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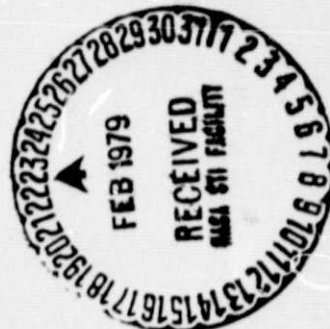
EVALUATION OF THE TECHNICAL FEASIBILITY AND EFFECTIVE COST  
OF VARIOUS WAFER THICKNESSES FOR THE MANUFACTURE OF SOLAR  
CELLS

JPL CONTRACT NO. 955077

FIRST QUARTERLY PROGRESS REPORT

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### ABSTRACT

Three wafering demonstration runs have been completed on the Yasunaga wire saw. Wafer thickness/taper uniformity is excellent. Many small problems have been encountered with Yasunaga accessories, slowing the effort. A wafer characterization cycle has been defined and will be initiated during the next period.



## 2. Introduction

Today, the most expensive part of a silicon solar cell is the high purity silicon from which it is fabricated. In terms of watts delivered per kilogram of silicon used, today's cells are far more expensive than most potential photovoltaic applications can tolerate. The purpose of this program is to evaluate the impact on these costs of thin wafer/low kerf loss wire sawing of silicon using the Yasunaga wafering system. The optimum wafering conditions for best technical and economic results will be determined by evaluating the effect on cell performance of a matrix of wafering parameters.

The JPL owned Yasunaga YQ-100 is a continuous-feed multiple-wire free-abrasive saw. It is described in the LSSA Project Task Report, "Multi-Wire Slurry Wafering Demonstrations," No. DOE/JPL-1012-78/7.

## 1. Summary of Progress

### A. The Wire Saw

During the first calendar quarter of this program, the Yasunaga YQ-100 Wafering System (Figure 1) was delivered and installed and a sawing parameter matrix study was begun. The saw is a free-abrasive multiple-loop single wire machine. It is described as production proven by its distributor and is promised to provide the least surface damage of any wafering method. In addition to the saw, the system as delivered included a grooving jig set and chaser bits for grooving the wire guide rollers, two rotary jig tables, a carriage winder with tension control, a wire transport cassette with stand and triangle cartridge, and a wire respooler set. A micrometer depth gauge for automatic depth control was not delivered with the machine and is now on order.

Installation of the system and a first wafering run were done with the assistance of a wafering engineer from Geo-Science Corporation, Yasunaga's U.S. representatives. Prior to beginning the planned wafering matrix, various pieces of single crystal silicon were mounted and sliced to develop technician familiarity with the machine and its operation.

The operation is straight forward. Prior to set-up, wire is wound at the prescribed tension onto a delivery spool. The spool is mounted on the saw and the saw spindle



drag is set to establish the wire tension for the whole run. The wire is drawn from the spool around rollers and the rocker arm of the constant tension system and then around and around the grooved drive and idler rollers of the triangular cartridge. The spacing of the grooves of these rollers, and therefore, the spacing between wire turns determines the wafers/cm yield. From the cartridge the wire travels over the other side of the rocker arm and take-up rollers and onto the take-up spool. The three roller cartridge can be pre-wound off of the machine and transferred to it, a standard production procedure. Stringing the wires is a 20-30 minute operation. The ingot to be sliced is mounted in a cast ceramic mold using a hot melt dop wax. Compressed air is used to protect the bearings and stir the slurry. The pressure of the wires against the silicon per cm of kerf is adjusted by loading a counterbalance pulley on the ingot support (as the run progresses and the wire/silicon contact varies, the loading must be continuously manually adjusted).

Start-up only requires that the air and pump are turned on and the wire drive and advance are slowly turned on up to the desired rates. When the system is running well, wafering can continue to completion with no operator attention required except to maintain constant wire loading.

At the completion of the run, ingot removal is best effected by cutting all the wires. This avoids problems with cemented abrasive between the wafers and prevents wafer breakage and surface damage. Kerosene is used to clean the machine. It is pumped through the slurry delivery system to remove all the abrasive and oil. Only when the machine is clean and dry can the air to the bearings be turned off. Wafers are cleaned in alcohol to remove the hot melt wax, Safety-Keen, a filling station solvent, to remove slurry, and detergent in an ultrasonic bath to prepare them for etching or characterization. Care is taken to avoid introducing new damage. Although operator experience will certainly reduce the time necessary to perform many set-up and cleaning steps, a first impression of the system is that its operation will be substantially more labor intensive than anticipated. The maximum workpiece size which will fit in the saw is appreciably less than the advertised 100 mm when either of the precision rotary tables supplied with the saw are used; the compressed air requirements were greater than expected, a 5HP compressor was obtained to serve the system. Slurry maintenance is not unimportant. The abrasive has a tendency during down time to settle out of the suspension oil and clog pump hoses. Repeated wire breakage and a rupture of the slurry delivery hose were minor problems overcome. On some runs, some wires

began cutting faster or slower than the rest. The cause of this problem, which has also been observed at GeoScience, is not clear at present. Reducing the pressure of the wires against the ingot allows the trailing wires to catch up, but the resulting cutting speeds are unacceptably low. Many days have been lost because of various shortcomings in the engineering of the wire respooler set, a Yasunaga supplied accessory (Figures 2 and 3). The purpose of this tool is to wind at a specified tension, wire from one spool, or reel, onto another which is compatible with the saw. (An adapter was designed and fabricated to handle the spools from the wire producer). The respooler motor lacks the power to continuously wind 8 mil diameter wire at the prescribed tension, the motor controller does not maintain a consistent speed, surges often causing the wire to kink and break, and finally, the traversing guide which is intended to lay the wire evenly upon the take-up spool is not synchronized with the rotation motor and often produces spools with wire badly overlapped and likely to break on the saw. This system will be modified for more dependable service. Often, wire wound at prescribed tension stresses the cast aluminum spools beyond their strength. Spools have broken here during or after winding (Figures 3 and 4), and occasionally have been received broken from GeoScience.

**model  
YQ-100**

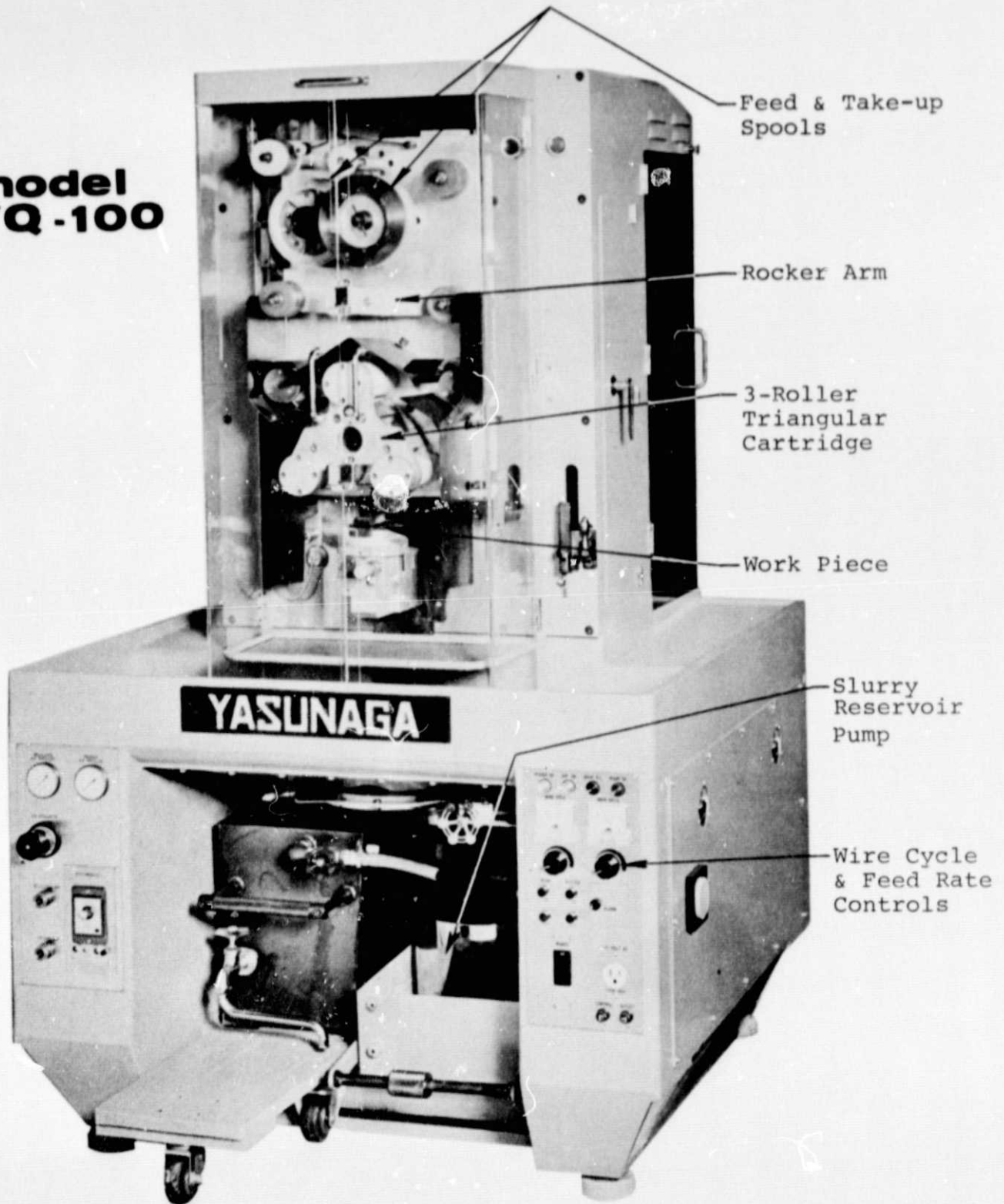


Figure 1. Yasunaga Wafering System (Yasunaga Photo)



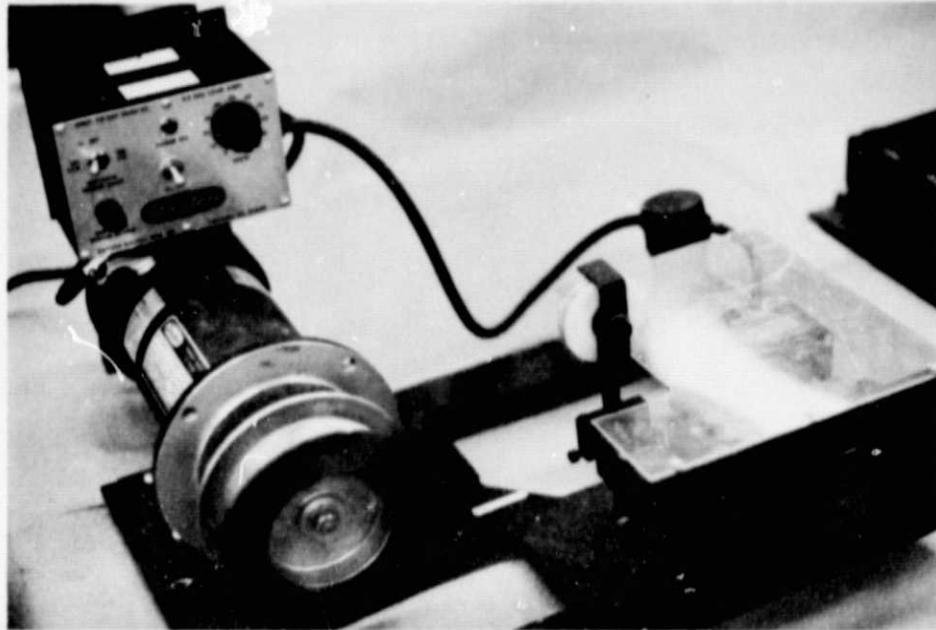


Figure 2. Spool Rewinder Set. Motor and controller at the left, the traversing guide roller and motor on the right.

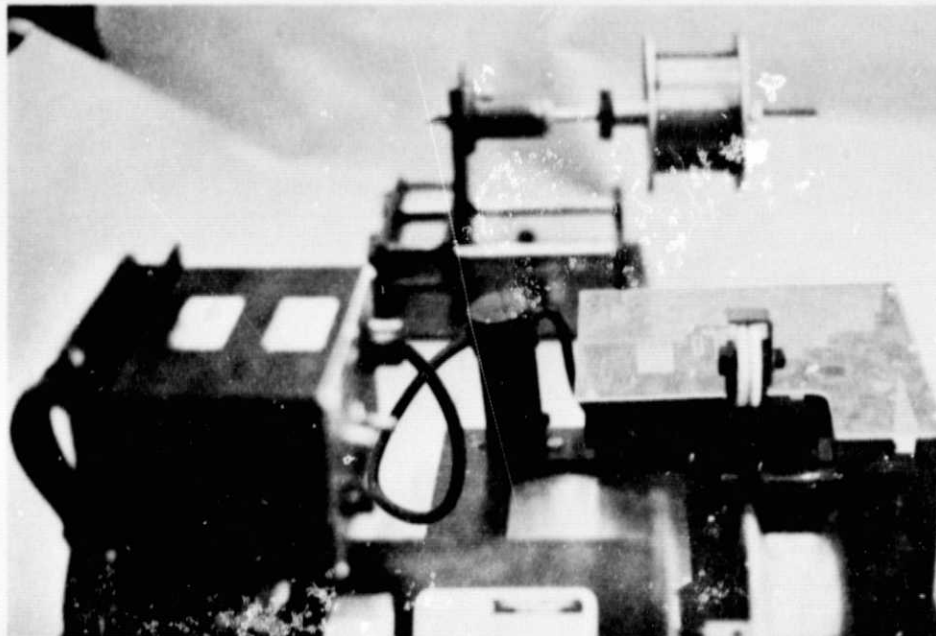


Figure 3. Spool Rewinder Set. A factory wire spool is seen on the feed spindle adapter in the rear. Wire tension on the take-up spool (foreground) is controlled by setting the drag on the feed spindle.



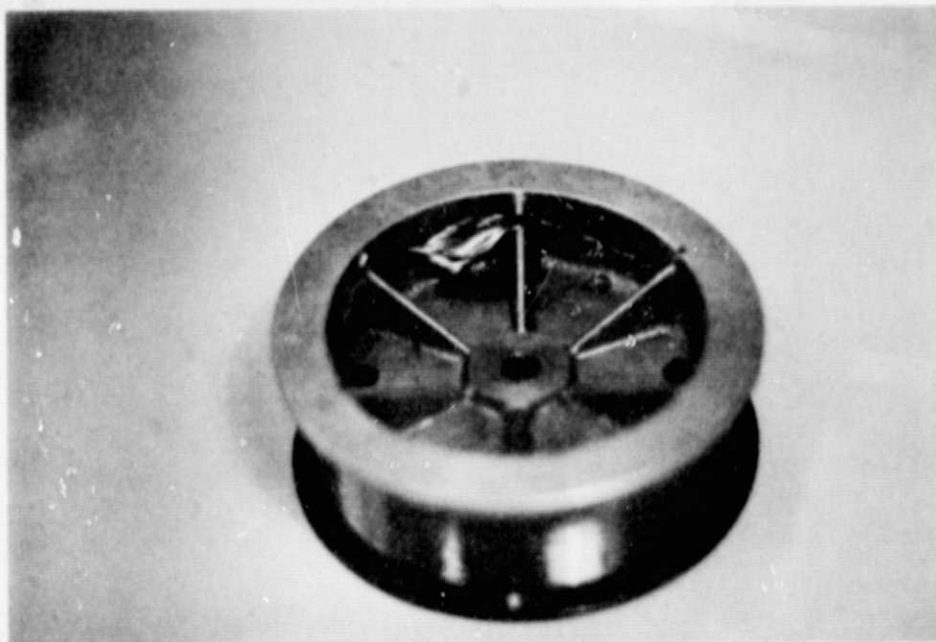


Figure 4. A wire spool which failed during respooling.



Figure 5. Wire spools showing stress failure.

## B. Wafering

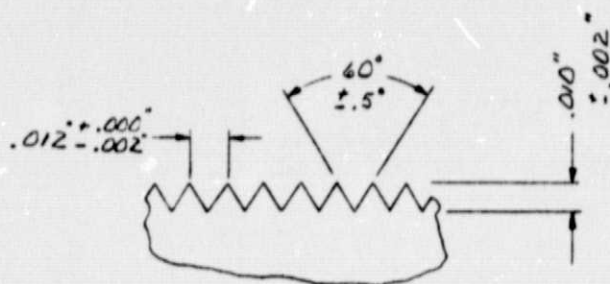
Six wafering parameters will most directly affect the economics of cell preparation. Three are considered prime wafering variables directly affecting wafer thickness and kerf loss and their evaluation will be our first priority. They are "pitch", abrasive diameter, and wire size. The total area of solar cells produced per unit weight of ingot depends directly on the wire spacing or roller groove pitch. The difference in area of yield of wafers/Kg ingot as a function of pitch in the planned demonstration runs is as much as 2X. Assuming that comparable cell efficiency can be obtained in thin cells as in thick, a small pitch can result in an appreciable photovoltaic power cost reduction. Three pitches, .3, .4 and .6 mm, four abrasive sizes, 5, 10, 15 and 30 $\mu$  and four wire diameters, 3, 4, 6 and 8 mil will be used. An engineering drawing for a .3mm chaser bit, a cutting tool for grooving the .3mm pitch rollers has been completed (Figure 6). The bit has been ordered. Assuming a kerf width approximately equal to the wire diameter plus 3 times the abrasive diameter, various combinations of the above parameters might produce wafer/kerf ratios of from 0.026 to 5.56. The most promising combinations in terms of realistic dimensions and economic feasibility will be tested in the coming months. The three secondary wafering parameters are wire feed rate, which directly affects add-on cost, and wire speed and loading, which impact wafer surface damage and therefore, materials and processing costs.

Approximately seventy-five wafers are being cut per demonstration run. Runs yielding greater than 200 wafers each will impact labor, machine time and wire useage rates significantly.

A total of thirty sawing demonstration runs are tentatively planned. these were selected from the matrix of 48 possible combinations of wire diameter, abrasive size and roller pitch. Runs were chosen from the complete list by selecting those which would be most effective based upon calculated weight percent yields (grams wafer per gram ingot > 33.9%, most yields are well above 50%, and by eliminating those calculated to yield an unrealistic (wafers < 4 mils thickness prior to etching) or impractical wafers >15.8 mils) product. The runs planned are given in Table I.

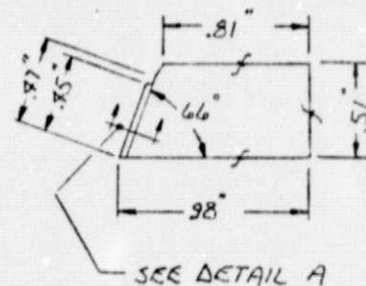
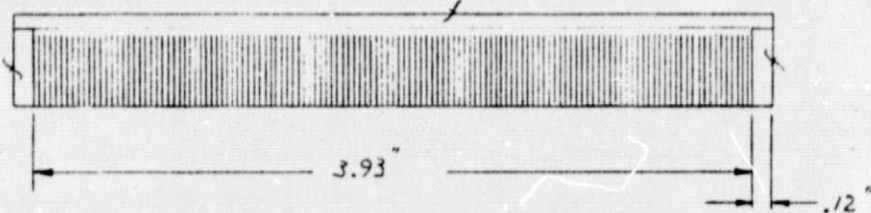
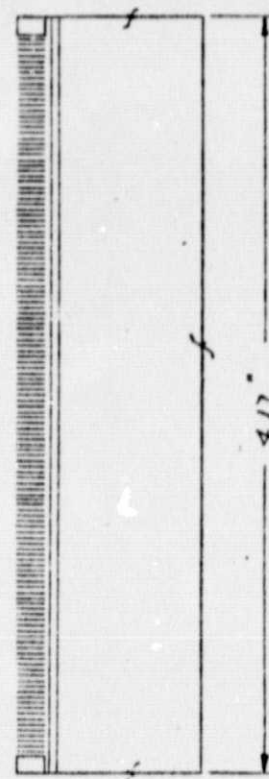
Three sawing runs have been completed (Table II). Run 1 was terminated prematurely when the wire broke. The failure was due to excessive wire wear when the wire was cutting the plaster mounting block as well as the silicon (in all cases, the silicon used for the demonstration runs will be 3" diameter, p-type .5-2 $\Omega$ cm single crystal). The wafers obtained are suitable for both characterization and cell processing. Nine wafers (three each from front, center and back) were measured for thickness and taper. Their uniformity was excellent (Table III). Run #3 was repeatedly bothered by a failure of the roller grooves to retain and guide the wires.

| APPLICATION |         |     | REVISION    |      |          |
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DETAIL A

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MATERIAL

FINISH

DO NOT SCALE DRAWING

CONTRACT NO.

APPROVALS

DATE

DRAWN

JG

8-7-78

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Fig. 6.3mm CHASER BIT

SIZE

A

CODE IDENT NO.

DRAWING NO.

5-85

SCALE NONE

SHEET / OF /



TABLE 1

| RUN NO. | WIRE (mil) | ABRASIVE (mm) | PITCH (mm) | CALCULATED (mil) |      | CALCULATED Weight%Yield | AREA YIELD/gm                  |
|---------|------------|---------------|------------|------------------|------|-------------------------|--------------------------------|
|         |            |               |            | Wafer            | Kerf |                         |                                |
| 1.      | 6          | .030          | .6         | 14.4             | 9.6  | 60                      | $7.2\text{cm}^2\text{g}^{-1}$  |
|         | 3          | .015          | .4         | 10.9             | 4.8  | 69.4                    | $10.8\text{cm}^2\text{g}^{-1}$ |
|         | 4          | .015          | .4         | 9.9              | 5.8  | 63                      | $10.8\text{cm}^2\text{g}^{-1}$ |
| 3.      | 6          | .015          | .4         | 7.9              | 7.8  | 50.3                    | $10.8\text{cm}^2\text{g}^{-1}$ |
|         | 3          | .030          | .4         | 9.2              | 6.5  | 58.6                    | $10.8\text{cm}^2\text{g}^{-1}$ |
|         | 4          | .030          | .4         | 8.2              | 7.5  | 52.2                    | $10.8\text{cm}^2\text{g}^{-1}$ |
|         | 8          | .005          | .6         | 15.0             | 8.6  | 63.5                    | $7.2\text{cm}^2\text{g}^{-1}$  |
|         | 8          | .010          | .6         | 14.0             | 9.6  | 59.3                    | $7.2\text{cm}^2\text{g}^{-1}$  |
| 2.      | 6          | .015          | .6         | 15.8             | 7.8  | 67                      | $7.2\text{cm}^2\text{g}^{-1}$  |
|         | 8          | .015          | .6         | 13.8             | 9.8  | 58.5                    | $7.2\text{cm}^2\text{g}^{-1}$  |
|         | 8          | .030          | .6         | 12.1             | 11.5 | 51.3                    | $7.2\text{cm}^2\text{g}^{-1}$  |
|         | 3          | .005          | .3         | 8.2              | 3.6  | 69.5                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 4          | .005          | .3         | 7.2              | 4.6  | 61                      | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 6          | .005          | .3         | 5.2              | 6.6  | 44.1                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 3          | .010          | .3         | 10.2             | 4.6  | 68.9                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 4          | .010          | .3         | 9.2              | 5.6  | 62.2                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 6          | .010          | .3         | 7.2              | 7.6  | 48.6                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 8          | .010          | .3         | 5.2              | 9.6  | 35.1                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 3          | .015          | .3         | 7.0              | 4.8  | 59.3                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 4          | .015          | .3         | 6.0              | 5.8  | 50.8                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 6          | .015          | .3         | 4.0              | 7.8  | 33.9                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 3          | 0.30          | .3         | 5.3              | 6.5  | 44.9                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 4          | 0.30          | .3         | 4.3              | 7.5  | 36.4                    | $14.3\text{cm}^2\text{g}^{-1}$ |
|         | 3          | .005          | .4         | 12.1             | 3.6  | 77.1                    | $10.8\text{cm}^2\text{g}^{-1}$ |
|         | 4          | .005          | .4         | 11.1             | 4.6  | 70.1                    | $10.8\text{cm}^2\text{g}^{-1}$ |
|         | 6          | .005          | .4         | 9.1              | 6.6  | 58                      | $10.8\text{cm}^2\text{g}^{-1}$ |



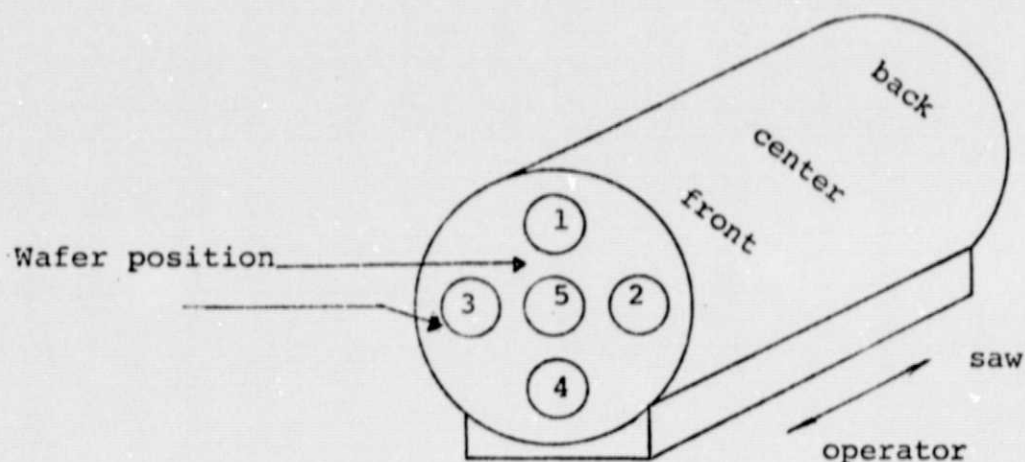
TABLE 1 CONTINUED

| WIRE<br>(mil) | ABRASIVE<br>(mm) | PITCH<br>(mm) | CALCULATED(mil) |      | CALCULATED<br>Weight%Yield | AREA YIELD/gm                       |
|---------------|------------------|---------------|-----------------|------|----------------------------|-------------------------------------|
|               |                  |               | Wafer           | Kerf |                            |                                     |
| 8             | .005             | .4            | 7.1             | 8.6  | 45.2                       | 10.8cm <sup>2</sup> g <sup>-1</sup> |
| 3             | .010             | .4            | 11.1            | 4.6  | 70.1                       | 10.8cm <sup>2</sup> g <sup>-1</sup> |
| 4             | .010             | .4            | 10.1            | 5.6  | 64.3                       | 10.8cm <sup>2</sup> g <sup>-1</sup> |
| 6             | .010             | .4            | 8.1             | 7.6  | 51.6                       | 10.8cm <sup>2</sup> g <sup>-1</sup> |
| 8             | .010             | .4            | 6.1             | 9.6  | 38.9                       | 10.8cm <sup>2</sup> g <sup>-1</sup> |

TABLE II

| SPECIFICATION OF PROSPECT                  | DEMONSTRATION          |                        |                        |
|--------------------------------------------|------------------------|------------------------|------------------------|
|                                            | #1                     | #2                     | #3                     |
| 1. Material                                | Silicon                | Silicon                | Silicon                |
| 2. Dimensions                              | 800x82mm               | 800x71mm               | 800x69mm               |
| 3. Machine No.                             | 1                      | 1                      | 1                      |
| <u>CUTTING CONDITIONS</u>                  |                        |                        |                        |
| 1. No. Wires                               | 75                     | 75                     | 75                     |
| 2. Roller Pitch                            | .6mm                   | .6mm                   | .4mm                   |
| 3. Wire Dia. (mil)                         | 6                      | 6                      | 6                      |
| 4. Type                                    | XLO Music              | XLO Music              | XLO Music              |
| 5. Strength (kg)                           | ~5.1                   | ~5.1                   | ~5.1                   |
| 6. Tension (kg)                            | 1.3                    | 1.6                    | 1.6                    |
| 7. Cycle Rate (cpm)                        | 50-55                  | 50-55                  | 55-60                  |
| 8. Feed Rate (mpm)                         | 9.6                    | 5-6                    | 6                      |
| 9. Wire Wear (mil)                         | .1-.4                  | ~.5                    | 5.7                    |
| 10. Wire Used (M)                          | 5500                   | 3400                   | 5610                   |
| 11. Wire Used (kg)                         | .78                    | .429                   | .80                    |
| 12. Abrasive Size/Type                     | SiC30 $\mu$            | 15 $\mu$ SiC           | 15 $\mu$ SiC           |
| 13. Suspension Medium                      | #3 Oil                 | #3 Oil                 | #3 Oil                 |
| 14. Prior Use                              | No                     | 0                      | 1                      |
| 15. 12/13                                  | 3/2                    | 3/2                    | 3/2                    |
| 16. Mean Weight gm/cm                      | 20                     | 20                     | 20                     |
| 17. Total Weight (kg)                      | 6-11.5                 | 6-11.5                 | 12.0                   |
| 18. Av. Kerf Length                        | 6.94mm                 | 6.94mm                 | 6.94mm                 |
| 19. Bond                                   | DeKhotinsky<br>#011425 | DeKhotinsky<br>#011425 | DeKhotinsky<br>#011425 |
| <u>WORKING EFFICIENCY</u>                  |                        |                        |                        |
| 1. Working Time                            | 13hr, 40min            | 10hr, 20min            | 9hr, 35min             |
| 2. Yield Unbroken/Total                    | 73/74                  | 71/75                  | 65/75                  |
| 3. Time of Unit Work                       | 11.08min               | 8.73min                | 8.89min                |
| 4. Total Area Cut (cm <sup>2</sup> )       | 3375                   | 3375                   | 3375                   |
| 5. Kerf Volume per Wire (cm <sup>3</sup> ) | 1.1                    | 0.89                   | 0.89                   |

TABLE III: UNIFORMITY OF WAFER THICKNESS  
MEASUREMENT ( $\mu$ )



|                     |        | Wafer Positions |     |     |     |      |
|---------------------|--------|-----------------|-----|-----|-----|------|
|                     |        | 1               | 2   | 3   | 4   | 5    |
| Demonstration<br>#1 | Front  | 402             | 397 | 401 | 394 | 402  |
|                     |        | 402             | 405 | 405 | 397 | 400  |
|                     |        | 402             | 398 | 400 | 395 | 400  |
|                     | Center | 401             | 400 | 400 | 395 | 399  |
|                     |        | 401             | 401 | 400 | 394 | 401  |
|                     |        | 401             | 402 | 402 | 396 | 403  |
|                     | Back   | 402             | 401 | 401 | 397 | 403  |
|                     |        | 400             | 397 | 399 | 393 | 398  |
|                     |        | 399             | 399 | 396 | 392 | 392  |
|                     | Front  | 315             | 321 | 328 | 326 | 324  |
|                     |        | 322             | 325 | 322 | 324 | 331  |
|                     |        | 326             | 328 | 331 | 333 | 328  |
|                     | Center | 326             | 327 | 329 | 332 | 331  |
|                     |        | 322             | 324 | 326 | 324 | 329  |
|                     |        | 327             | 334 | 338 | 333 | 332  |
|                     | Back   | 322             | 324 | 331 | 328 | 323  |
|                     |        | 328             | 326 | 329 | 327 | 327  |
|                     |        | 326             | 328 | 327 | 328 | 330  |
| Demonstration<br>#3 | Front  | 201             | 208 | 210 | 210 | 201  |
|                     |        | 198             | 209 | 206 | 206 | 200  |
|                     |        | 200             | 205 | 205 | 204 | 407* |
|                     | Center | 203             | 208 | 208 | 209 | 207  |
|                     |        | 198             | 202 | 204 | 206 | 203  |
|                     |        | 206             | 205 | 208 | 210 | 206  |
|                     | Back   | 199             | 201 | 202 | 206 | 201  |
|                     |        | 196             | 201 | 201 | 204 | 201  |
|                     |        | 192             | 194 | 196 | 198 | 196  |

\*Results from a wire jumping from its assigned roller groove to an adjacent groove.

Sample quantities of all the wafers will now be evaluated by defect mapping and others will be processed into solar cells. It was noted that the wires wander, wafers with surface steps up to 17 mils have been seen, when the pressure of the ingot against the wires is too great. Visible steps occur on the wafer surface when the run is interrupted apparently due to the change in temperature of all the elements of the system.

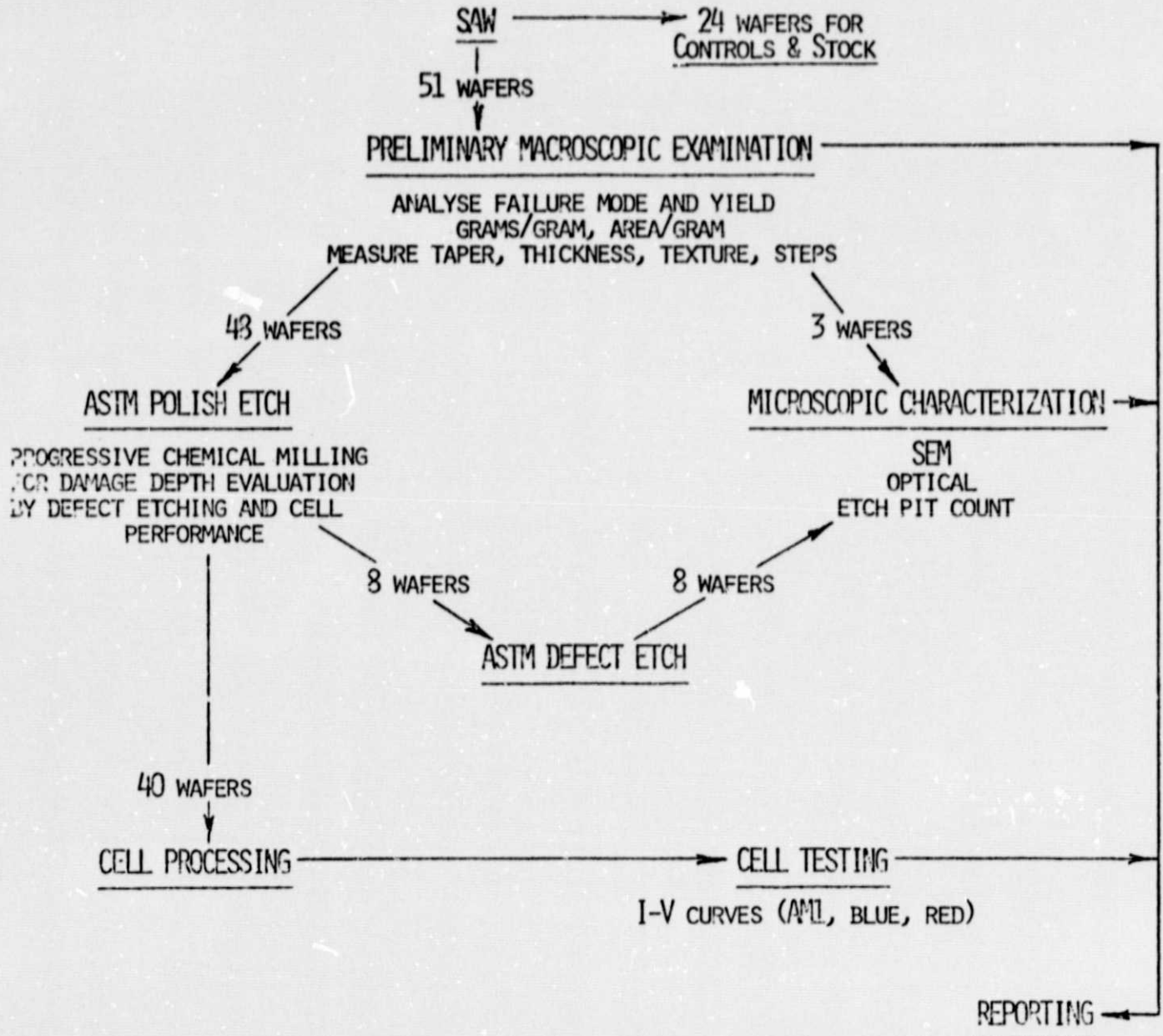
### C. Wafer Characterization

The characterization cycle for the wafers is shown in Figure 7. The watt/gram silicon economics of wafering is directly dependent upon total wafer surface area obtained per gram of ingot and upon the photovoltaic conversion efficiency of the wafers. On the Yasunaga system, roller pitch selection fixes the solar cell area/gram-ingot obtained. Photovoltaic conversion efficiency is a function of surface damage, degree of damage removal and cell thickness. The characterization cycle is intended to relate sawing parameters (abrasive size, wire pressure, wire speed, etc.) to surface damage and final wafer thickness to solar cell efficiency. The cycle includes preliminary macroscopic and microscopic examination of the as-sawn wafers, and evaluation of sawing damage depth by progressive chemical milling and etching of the wafer surface and by processing wafers which have been progressively milled into solar cells and characterizing the cells.



Figure 7

# WAFER CHARACTERIZATION CYCLE



EVALUATION OF THE TECHNICAL FEASIBILITY AND EFFECTIVE  
COST OF VARIOUS WAFER THICKNESSES  
FOR THE MANUFACTURE OF SOLAR CELLS

JPL CONTRACT NO. 955077



Milling and defect etches chosen to characterize sawing induced wafer surface damage are specified by ASTM Designation F47-70 (Annual Book of ASTM Standards, Part 8, Nov. 1978). The polish etch is a 5:10:14 HNO<sub>3</sub>:HF:Hac slow oxidizing dilute acid mixture. The dislocation etch is based on chromic acid (50μg CrO<sub>3</sub>, 100 ml H<sub>2</sub>O, 100 ml HF). Initial polish etching of wafers from demonstration runs 1-3 show finishes ranging from satin to high gloss depending on the amount of etching done. At 5, 10, 15, 20, 25μ removal per side, microscopic examination reveals successively less abrasion damage. A high gloss on wafers cut using 15μ abrasive was only achieved at >50μ removal.

State-of-the-art cell processing for the characterization cycle of the sawn and etched p-type wafers will include phosphorus diffusion for junction formation and Ti-Pd-Ag metalization. Two cm x two cm cells will be fabricated from the wafers for the characterization cycle, 3" cells will be processed for panels.

### Conclusions and Recommendations

The program is essentially on schedule. Too little data has been generated to draw any conclusions with reference to the final program objectives - the evaluation of the technical feasibility and effective cost of various wafer thicknesses for the manufacture of solar cells. Interim observations include that the process is very labor intensive and that some of this labor is due to problems with Yasunaga supplied equipment. Also, that when the saw runs well, the product is apparently very good and the yield high.

## Updated Program Plan

The program is on schedule as specified in the Contract Program Plan Table III. In light of the problems being experienced with the saw and its ancillary equipment, it is not certain that the schedule will be maintained. However, there are no JPL action items at this point in time.

PROGRAM PLAN/SCHEDULE (page 1 of 2)  
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TABLE III  
EVALUATION OF THE TECHNICAL FEASIBILITY AND EFFECTIVE  
COST OF VARIOUS WAFER THICKNESSES FOR THE MANUFACTURE

| TECHNICAL TASKS     |                                                                                | OF SOLAR CELLS |     |      |     |     |     |     |     |     |  |  |  |
|---------------------|--------------------------------------------------------------------------------|----------------|-----|------|-----|-----|-----|-----|-----|-----|--|--|--|
|                     |                                                                                | JUL            | AUG | SEPT | OCT | NOV | DEC | JAN | FEB | MAR |  |  |  |
| I PROCESSING        |                                                                                |                |     |      |     |     |     |     |     |     |  |  |  |
| A                   | Sawing Thin Wafers                                                             |                |     |      |     |     |     |     |     |     |  |  |  |
| B                   | Fabricate Ultrathin Cells                                                      |                |     |      |     |     |     |     |     |     |  |  |  |
| C                   | Fabricate Panels                                                               |                |     |      |     |     |     |     |     |     |  |  |  |
| II CHARACTERIZATION |                                                                                |                |     |      |     |     |     |     |     |     |  |  |  |
| A                   | Characterize wafers as a function of sawing parameters                         |                |     |      |     |     |     |     |     |     |  |  |  |
| B                   | Characterize cells as a function of wafer thickness                            |                |     |      |     |     |     |     |     |     |  |  |  |
| C                   | Characterize Modules                                                           |                |     |      |     |     |     |     |     |     |  |  |  |
| III. ANALYSIS       |                                                                                |                |     |      |     |     |     |     |     |     |  |  |  |
| A                   | Economic Evaluation of various thickness of wafers                             |                |     |      |     |     |     |     |     |     |  |  |  |
| B                   | Determine Panel Array                                                          |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | Stiffness Requirements and                                                     |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | Associated Weight & Cost                                                       |                |     |      |     |     |     |     |     |     |  |  |  |
| C                   | Evaluate Cells and Modules Compared to Conventional 8 12 mil cells and modules |                |     |      |     |     |     |     |     |     |  |  |  |
| IV REPORTING        |                                                                                |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | Monthly technical and financial reports                                        |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | Quarterly Reports                                                              |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | Program Plan/Schedule Baseline                                                 |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | Cost Estimated                                                                 |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | Draft Final Report                                                             |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | Milestones                                                                     |                |     |      |     |     |     |     |     |     |  |  |  |
|                     | 1st Thin Wafers Sliced                                                         |                |     |      |     |     |     |     |     |     |  |  |  |



Type 9 = 0.0001 %



### Planned Activities

Wafering to complete the proposed matrix (Table I) will continue. This will require renovation of the wire respooling set so that it is capable of satisfactorily winding wire greater than and less than 6 mil diameter. 0.3mm pitch rollers will be prepared and their feasibility evaluated. All steel spools will be fabricated and put into use. The problem of non-uniform cutting rates of wire will have to be solved. Wafer characterization as per the previously described cycle (Figure 7) will begin. The applicability of the ASTM etches to the needs of this program will be evaluated.

Cell fabrication as a wafer characterization tool will also begin in the coming quarter. Cell performance of wafers etched to various depths after sawing will be used to evaluate sawing damage depth. Cell performance as a function of final cell thickness will also be characterized. In the next period we will begin to compile economic data to evaluate the impact of thin wafer/low kerf loss sawing using the Yasunaga system. The module design requirement study for thin cells will be started on schedule. That data will be submitted to JPL in SAMICS form for integration into the LSA program.

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